International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 7, Issue 3, Jun 2017, 67-78

DESIGN AND IMPLEMENTATION OF SENSOR-BASED DECTION SYSTEM FOR STANDALONE ACCIDENT

GEA-HEE KIM[1], SEON-MIJEONG[2], HYEONTAEHA[3], HYUNG-JINMUN[4] & CHANG-GEUN KIM[5]

[1,2,5] Gyeongnam National University of Science and Technology, Korea

[3]Gyeongsang National University, Korea

[4]Division of Information and Communication Engineering, Baekseok University, Korea

ABSTRACT

Background/Objectives

IoT provides living convenience and the development of IoT makes it possible to interwork different objects so it is applied to daily life, medical care, and vehicles.

Findings

With the accelerated convergence of vehicles and IT, researches on the detection of traffic accident have been in progress. In particular, a standalone accident by careless driving at dawn ranked highest reaching 13.5%. There are many researches of a warning system for a risky condition while driving a vehicle, whereas there is a lack of researches on the detection and responsive measure for a traffic accident.

Methods

This paper aims not only to design a system to detect a standalone accident by utilizing a vehicle sensor based on IoT but to propose a procedure that links the accident to an emergency rescue service.

Improvement/Applications

In the case when a vehicle was inside a section of a road within the average passage time, the system detected an accident based on the driving record and behavior. We utilized the curve road and zigzag driving detection system presented in preceding researches and the detection rate reached 0.836 on a straight road and 0.742 on a curve road.

KEYWORDS: IoT, Standalone Accident, Accelerometer, Gyro Sensor, Accident Detection, Road-Side Equipment & Communication between Vehicles

Received: Apr 01, 2017; **Accepted:** Apr 20, 2017; **Published:** May 04, 2017; **Paper Id.:** IJMPERDJUN20179

Original Article

INTRODUCTION

IoT (Internet of Things), a convergence of human, things, and services, is a network that forms intellectual relations through diversified information processing without human intervention[1-3]. Recently, various researches have been in progress to materialize the intelligent vehicle and, particularly, the standardization of V2X (Vehicle to Everything) has begun to enhance safety against accidents[4]. In spite of those researches, the complete prevention of traffic accidents has not been made. Currently, there is a high fatality rate of accidents from over speed driving, drowsy driving, and driving in rain. The number of deaths by traffic accidents during the past 3

years is as shown in figure 1.

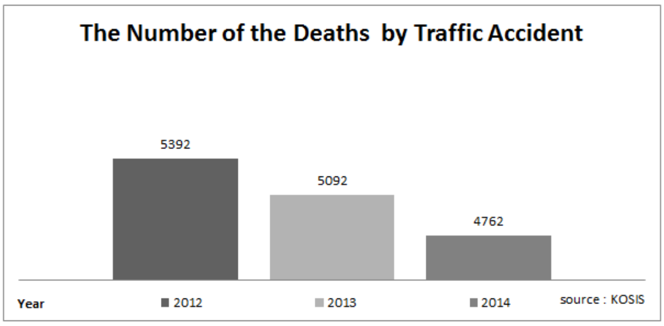

Figure 1: The Number of the Deaths by Traffic Accident During the Past Three Years

In particular, the fatality rate of a standalone accident from careless driving at dawn turned out to be 9 times higher than the fatality rate of other traffic accidents. SBD in the U.K. analyzed that the number of deaths by traffic accidents decreased by 5-10% with the emergency rescue response when an emergency notification system was adopted by the STORM project[5].

This paper is about a system that detects an accident after RSU's analyzing and collecting the record of data from a sensor installed in a vehicle in the case when there is no record indicating that a vehicle from a start point passed an end point. We propose a standalone accident detection system that requests emergency rescue in the case of an accident.

RELATED WORKS

Accelerometer and Angular Speed Sensor

Accelerometer returns the value of roll, pitch, and yaw. Although roll returns the rotation value to X-axis, pitch does to Y-axis, and yaw does to Z-axis, yaw has the same direction of the gravity so it is not possible to measure the value. The dotted line of accelerometer (A) in figure 2 represents acceleration and the bold arrow represents the value of acceleration of gravity. Accelerometer measures dynamic acceleration and static acceleration; the former equals acceleration of gravity and the latter represents the value that comes from vibration and impact. Accelerometer can be used in various fields like measuring vibration, impact, acceleration, and noise or analyzing frequency. Angular speed sensor (B) is used to figure out the direction finding the rotating angle of each axis. After setting the direction at the degree 0, the sensor shows how many degrees it rotates based on the current direction[6,7].

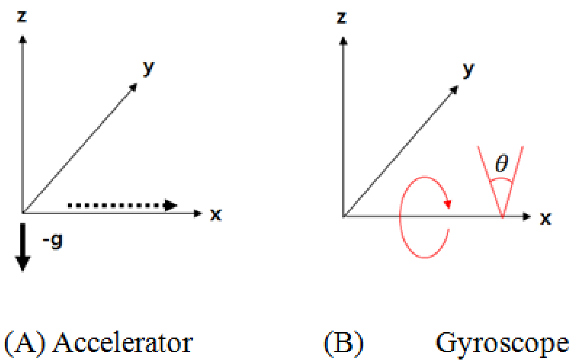

Figure 2: Sensor Fundamentals

DSRC (Dedicated Short Range Communication)

DSRC, Dedicated Short Range Communication, has 5.8GHz frequency band and it communicates utilizing the active mode[8]. RSE (Roadside Equipment) [9,10] and OBU (On-Board Unit)[11,12] with electric generators employ the way to use the independent communication channel; one RSE supports multiple connections of OBUs and reuses frequency, with which a transmitter with the output power of 10mW can secure communication area[13]. As it secures high success rate of communication and high speed mobility, it has been used for a traffic information collection system such as the bus information system.

Curve Road Detection and Zigzag Driving Detection System

In the preceding research, the curve road was detected by utilizing the data of azimuth of the direction sensor. After calculating the curvature value by substituting the data of accelerometer to proposed curvature calculating formula, it was verified to be the curve road when the outcome was within the range of threshold [14].

Zigzag driving detection was made by analyzing a driver's behavior and calculating moving distance and position after collecting data from accelerometer and direction sensor. When the lateral driving distance was twice longer than a straight driving and it was within the range of threshold, it was verified to be zigzag driving [15].

Warning Information Provision System

Existing researches adopt the way to notify a driver of a risky condition by using various data from driving process of a vehicle. As the research to detect a vehicle collision accident caused by zigzag driving, the method that detects a collision with an angular speed sensor was proposed. Risky driving can be sensed with a vehicle with AOBU (Advanced On-Board Unit) which is able to do vehicle-vehicle and vehicle-infra communication, utilizing data collected by angular speed sensor. Although the warning transmission method basically uses vehicle-vehicle communication, in the case of a communication interruption, it transmits the warning information to the following car via vehicle-infra communication [16].

PROPOSED SYSTEM MODEL

Utilizing RSU, the proposed system model employs soft handoff method tracking information of a running vehicle. We also propose a standalone accident detection system with which the RSU management system collects sensor values of a vehicle and the agent system analyzes the accident in the case when normal handoff is not made within the average waiting time.

Architecture of Standalone Accident Detection System

There are a number of RSUs and vehicles move along with the road. Whenever a vehicle gets out of the wireless coverage of a given RSU, handoff with the next RSU is made. At the moment, if handoff is not made by RSU detecting the direction of the vehicle on the pathway and the loss of communication occurs, RSU management system collects sensing data of the target vehicle. With sensing data transmitted to the management system and virtual sensing technology of the agent system, the odds of accident are predicted. With the case verified as an accident, it is followed by emergency rescue service in the structure. The system structure of a standalone accident detection system in this paper is as shown in figure 3.

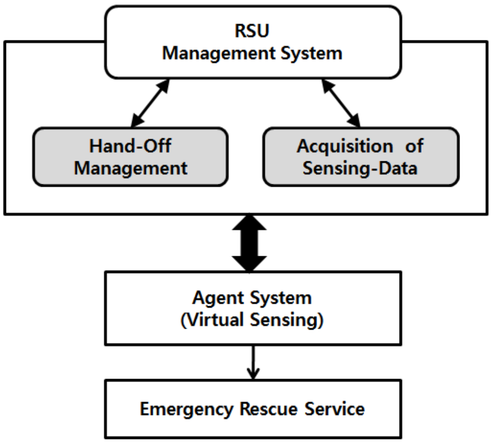

Figure 3: Architecture of the Stand Alone Accident Detect System

As seen in figure 4, RSUs are installed every 1000 meters and the start point of the section is A and the end point is B. The end point, B, becomes the end point and the start point at the same time. The communication service adopts DSRC transmission output and the communication distance adopts Class4 (up to 1000meters).

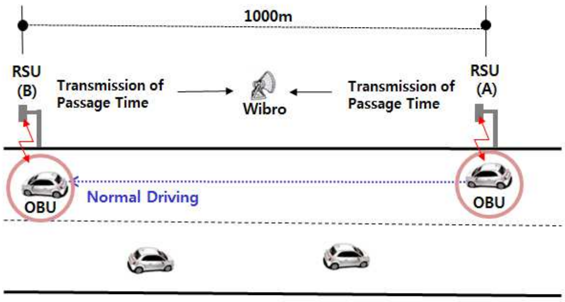

Figure 4: Scanning Start Point And End Point

As a vehicle passes the start point, A, the OBU installed in the vehicle transmits ID and the passage time of the vehicle to RSU. Collected information at the time is transmitted to the end point, B, via WiBro. The center computes the passage average speed with the passage time of the vehicle and distance transmitted to a control unit and predicts the time at which the vehicle passes B.

$$time_b = \left(\frac{1}{avgSpeed} \cdot \Delta ab\right) + time_a \tag{1}$$

The formula to compute the time, by which the vehicle passes B, equals (1) and the parameter value is as shown in table 1.

Table 1: Parameter to Calculate Passage Time

Parameter	Description
$time_a$	*Passage time the A*
$time_b$	*Passage time the B*
Δab	*Distance between A and B*
Avg Speed	*Average Speed*

In the case of figure 4, the average waiting time was set as predicted time for the vehicle to pass B with plus or minus 10 minutes. When the vehicle passes B within the average waiting time, the system resets the previous information

of the vehicle and sets B as the start point. Figure 5 and figure 6 illustrate each vehicle driving on the straight and curve road and it was divided into normal, resting, and accident vehicle.

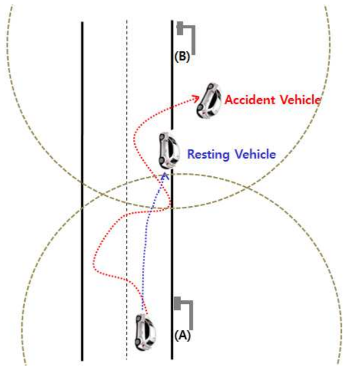

Figure 5: Scanning Start Point and End Point

The information of the normal vehicle is reset at the point B. However, in the case when the vehicle passed A but did not arrive at B within the average waiting time and reset was not made, it is considered as the accident or resting vehicle.

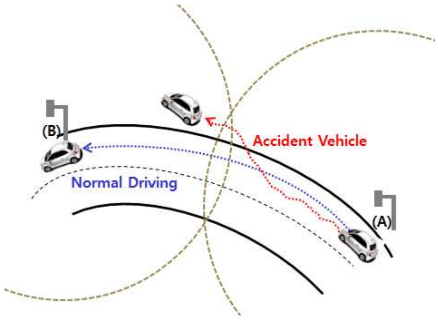

Figure 6: Scanning Start Point and End Point

Architecture of System for Standalone Accident

The section where a standalone accident occurs for a driver to be in danger is usually a road with light traffic at dawn as seen in related researches. In order to detect the accident, tracking the vehicle should be carried out first. Although ways to track running vehicles can be variously designed, RSU appears to be ideal.

Process to Obtain Information by RSU

The RSU architecture of the proposed system is as shown in figure 7. A vehicle periodically passes RSU, driving on a road; at the time, with data obtained from RSU, RSU transmits ID and the passage time of the vehicle to next RSU. Once the vehicle passes next RSU, reset is made.

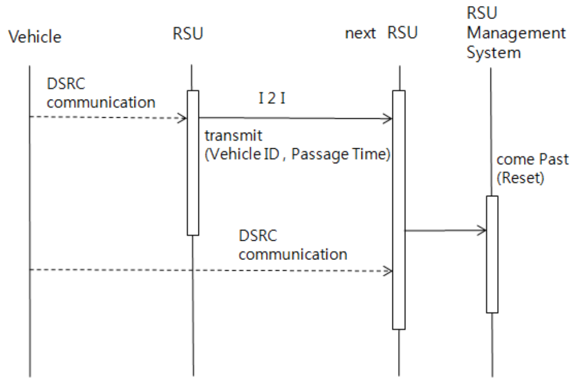

Figure 7: Passage through Start Point and End Point of the Section

When the signal that the vehicle passed the point within the average waiting time isn't sent to next RSU, the RSU management system sends a tracking beacon to a vehicle inside the wireless coverage. As shown in figure 8, once the transmission between RSU and the vehicle is made, sensing data from the vehicle is collected.

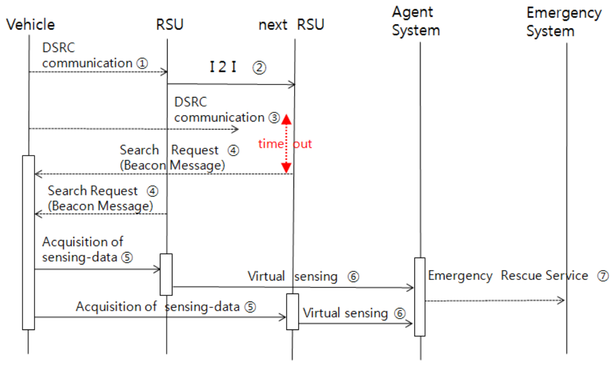

Figure 8: Process to Verify Vehicle Accident

Sensing Data Processing

The structure of the proposed system is illustrated in figure 9 and consists of 4 steps.

Step 1: The start point obtains ID and the passage time of a vehicle and transmits the information to the end point. RSU Management System determines the average waiting time after computing the driving time and distance.

Step 2: Upon passing the end point within the average waiting time, reset is made and the end point is assigned as the start point. Unless it passes the end point within the average waiting time, searching for the vehicle, collected sensing data is transmitted to the agent system.

Step 3: The agent system applies the data from the RSU Management System to virtual sensing technology to verify if an accident occurred.

Step 4: In the case of an accident vehicle, the emergency rescue service is provided; in the case of a resting vehicle, the analysis service to the vehicle is reset.

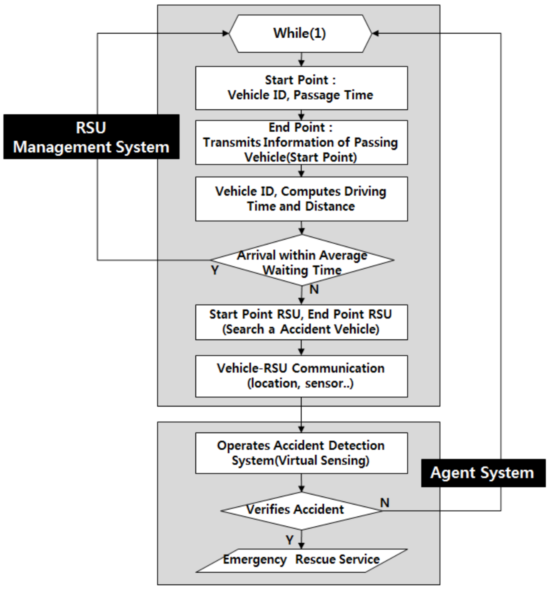

Figure 9: Accident Analyzing Process of RSU Management System and Agent System

SIMULATION RESULT AND ANALYSIS

Simulation Environment

Simulation was conducted by Unity 5 of Windows 7. The Environment of the road is as shown in table 2. It was a 2-lane road without a median strip and the design speed was set from 50 to 80km. The impact severity was 160KJ and a guardrail at the level of SB4 was installed. Simulations per each driving condition for 15 times were conducted and moving paths were described with solid lines.

Table 2: The Environment of Simulation

Environment	Description
Design speed	50~80km/h
Impact severity	160 KJ
Guardrail	SB4
Road width	two-lane road

With the assumption that the passage record of a vehicle is not sent to RSU, a standalone accident was verified by collecting sensing data of the vehicle. Under the condition that the curvature threshold range is 0.001~0.066 based on the curve road detection system and the zigzag driving threshold range is $0.22 \le cv \le 0.72$ based on the zigzag driving detection system in preceding researches, either curve road driving or zigzag driving was verified. Even though the type of an accident varies from rear-end and head-on collisions to a crash from zigzag driving, these rear-end and head-on collisions are excluded in the research since the system detects the accident when parking or stopping is made inside a section.

Standalone Accident Detection in Straight Road

Figure 10 illustrates the simulation to detect an accident in a straight road. The output of the simulation is as shown in table 3; X-axis represents vertical angle, Y-axis represents horizontal angle, and Z-axis changes according to the driving direction. The result that the value of Y-axis changes into 0.0 when Time(sec) was 4.0 and 6.0 indicates that there was a change in the height of the vehicle. Even though considering a margin of error, these outputs with the change value of a sensor can be used as important data to recognize an accident. With the curvature value, 0.00087, it is not a curve road

and with the value of zigzag driving, 0.189, which is out of the range of threshold; it is not verified as an accident.

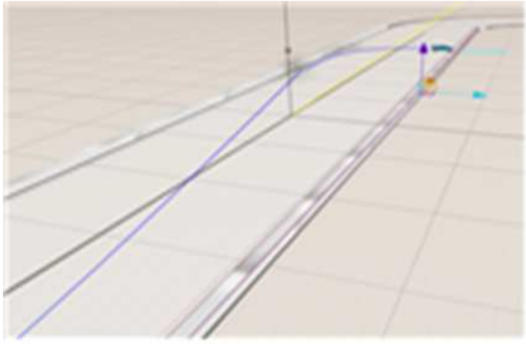

Figure 10: Accident Detection on Straight Road

Table 3: Driving Record on Straight Road

Time(sec)	Axis-X	Axis-Y	Axis-Z
0.0	5.5	0.0	-53.1
1.0	5.5	0.1	-50.1
2.0	3.9	0.1	-39.7
3.0	0.6	0.1	-22.6
4.0	-4.6	0.0	2.4
5.0	-9.4	0.1	31.0
6.0	1.6	0.0	53.5
7.0	8.8	0.1	52.8

Figure 11 illustrates the accident detection in a straight road. In table 4, the value of Y-axis changed into 0.0 in Time (sec) 7.0 and an impact was found in Time (sec) 7.22. Because the curvature value is 0.08547, which is out of the range of the threshold, and the value of zigzag driving is 0.621, which is inside the range of the threshold, it is verified as an accident.

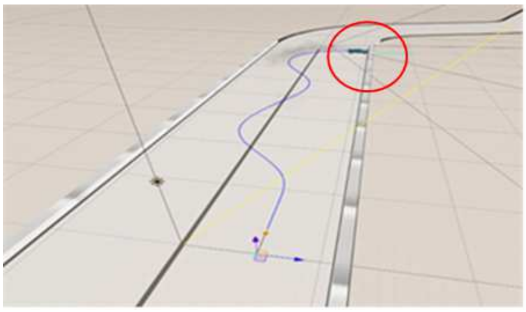

Figure 11: Zigzag Driving Detection on Straight Road

Table 4: Zigzag Driving Record on Straight Road

Time(sec)	Axis-x	Axis-y	Axis-z
0.0	5.5	0	0
1.0	5.5	0.1	0.3
2.0	3.9	0.1	3
3.0	0.6	0.1	10.9
4.0	-1.9	0.1	21.8
5.0	0.4	0.1	38.2
6.0	-2.5	0.1	58.6
7.0	5.1	0.0	77.7
8.0	8.8	0.1	76.7

Table 5: Accident Detection Record of Zigzag Driving on Straight Road

Time(sec)	Speed	Weight	Angle	Power
7.22	4.938685	0.999999	66.93777	10.3239

Standalone Accident Detection on Curve Road

Figure 12 describes the accident detection on a curve road. In table 6, the values of Y-axis changed into 0.0 in Time(sec) 4.0, 5.0, 6.0, 7.0, 8.0 as the vehicle made a change of direction. The curvature value is 0.0024 and the zigzag driving value is 0.198, which is not verified as an accident.

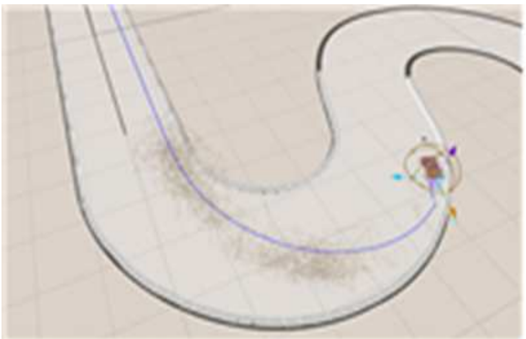

Figure 12: Accident Detection on Curve Road

Table 6: Driving Record on Curve Road

Time(sec)	Axis-X	Axis-Y	Axis-Z
0.0	7.8	0	105
1.0	7.8	0.1	104
2.0	7.8	0.1	95.7
3.0	7.8	0.1	78.2
4.0	7.8	0.0	53
5.0	7.8	0.0	53
6.0	7.8	0.0	-20.8
7.0	11.6	0.0	-67.6
8.0	49.6	0.0	-81.8
9.0	54.2	0.1	-76.8

Figure 13 describes the detection of an accident by zigzag driving on a curve road. In table 7, the values of Y-axis changed into 0 in Time(sec) 7.0, 8.0, 9.0 and an impact was sensed in Time(sec) 9.63, 9.66. The curvature value is 0.00457 and the value of zigzag driving is 0.592, which is verified as an accident.

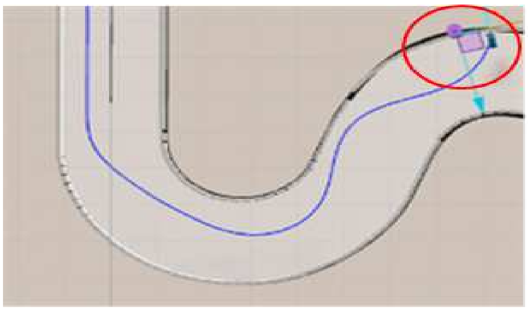

Figure 13: Detection of Accident by Zigzag Driving on Curve Road

Table 7: Zigzag Driving Record on Curve Road

Time(sec)	Axis-X	Axis-Y	Axis-Z
0.0	-5.2	0	14.4
1.0	-5.2	0.1	11.4
2.0	-5.2	0.1	2.9
3.0	-5.2	0.1	-12
4.0	-5.2	0.1	-30.1
5.0	-4.3	0.1	-52.5
6.0	9.8	0.1	-68.6
7.0	29.8	0.0	-78.3
8.0	47.5	0.0	-60.5
9.0	67.4	0.0	-39.8

Table 8: Accident Detection Record of Zigzag Driving on Curve Road

Time(sec)	Speed	Weight	Angle	Power
9.63	5.666438	0.999999	18.35359	1.591774
9.66	2.03076	0.99999	67.92907	1.770858

Results and Analysis

As a result of simulations, the outcome of the detection rate 0.836 on a straight road and 0.742 on a curve road was obtained. It is likely that the detection rate on a curve road is lower than a straight road because of the features of a curve road that causes errors of a sensor.

While existing researches have been confined to notify drivers and passengers of risky conditions by a risk warning model, this proposed model is designed to fully secure the occupants' safety by actively responding to an accident by improving earlier researches. Table 9 compares the existing model with the proposed model in terms of active response and safety in an accident. Although the existing model provides a warning service to zigzag driving, this proposed research connects it to be followed by accident detection and the emergency rescue service.

Table 9: Existing Model vs Proposed Model

Article	Existing Model[6]	Proposed Model
Emergency Response Service	X	O
Situation of on Accident Detection	O	O

CONCLUSIONS

This research was conducted to save lives from standalone accidents that occur on a national highway with light traffic at dawn by missing the critical time. As monitoring technology to verify an accident, we used the sensor making it possible to respond to the accident and we proposed a standalone accident detection system to provide the emergency rescue service.

Utilizing the threshold range of curve road and zigzag driving detection system of preceding researches, this proposed system was able to verify the accident. In the case of an accident, the accident detection rate reached 0.836 on a straight road and 0.742 on a curve road.

As following researches, a research to improve the accident detection rate by combining a voice sensor with lane recognition technology is required.

- Md. Syedul Amin, Mamun Bin Ibne Reaz, Salwa Sheikh Nasir, Mohammad Arif Sobhan Bhuiyan, “Low Cost GPS/IMU Integrated Accident Detection and Location System”, Indian Journal of Science and Technology,2016 Mar, 9(10), Doi no:10.17485/ijst/2016/v9i10/80221
- M. Samarasimha Reddy, K. Raghava Rao, “Fire Accident Detection and Prevention monitoring System using Wireless Sensor Network enabled Android Application”, Indian Journal of Science and Technology,2016 May, 9(17), Doi no:10.17485/ijst/2016/v9i17/93097

REFERENCES

1. *Seung -Soo Shin, Gyoo- Soo Chae, Tae-Hyun Lee, “An Investigation Study to Reduce Security Threat in the Internet of Things Environment”, Journal of IT Convergence Society for SMB, 2015, 5(4):31-36*
2. *Byung Il Kwak, Mi Ran Han, Ah Reum Kang, Huy Kang Kim, “A study on detection methodology of threat on carsfrom the viewpoint of IoT”, Journal of The Korea Institute of Information Security & Cryptology, 2015, 25(2)*
3. *Gartner, http://www.gartner.com/newsroom/id/2905717, 2014*
4. *Eunbi Jeong, Cheol Oh, Kyeongpyo Kang, Younsoo Kang, “Development of Traffic Safety Monitoring Technique by Detection and Analysis of Hazardous Driving Events in V2X Environment”, The Journal of The Korea Institute of Intelligent Transport Systems, 2012, 11(6):1-14*
5. *“Result of Characteristic Analysis on Single Vehicle Accident”, Samsung Traffic Safety Research Institute*
6. *http://smtfocus.co.kr/article/articleView.asp?idx=706*
7. *Moon-Seol Kang, Yu-Sin Kim, “Design and Implementation of a Motor Vehicle Emergency Situation Detection System”, J. Korea Inst. Inf. Commun. Eng, 2013, 17(11):2677~2685*
8. *Oh JongTaik, “United States 5.9GHz, Next Generation DSRC Frequency and Current State of Standards”*
9. *J. Lee, C. Kim, “A roadside unit placement scheme for Vehicular Telematics networks”, LNCS 6059, pp.196-202, 2010.*
10. *C. Lochert, B. Scheuermann, C. Wewetzer, A.Luebke, M. Mauve, “Data aggregation and roadside unit placement for a VANET traffic information system”, VANET2008, pp.58-65, 2008.*
11. *Se-Jun Park, Tae-Kyu Yang, Seung-Sun Yoo, “A study on LBB System Using the OBU”,The Journal of Korean Institute of Information Technology, 2009, 7(3):64-73*
12. *Woo, Samuel, Hyo Jin Jo, and Dong Hoon Lee,“A practical wireless attack on the connected car and security protocol for in-vehicle can”, Intelligent Transportation Systems, 2014, 16(2):993-1006*
13. *http://www.kssn.net, DSRC Standards Research for IT*
14. *Gea-Hee Kim, Seon-Mi Jeong, Hyung-jin Mun, Chang-Geun Kim, “Design of Curve Road Detection System by Convergence of Sensor”, Journal of digital convergence, 2016 Aug, 14(8):253-259*
15. *Seon-Mi Jeong, Gea-Hee Kim, Hyung-Jin Mun, Chang-Geun Kim, “Design and Implementation of a System to Detect Zigzag Driving using Sensor”, Journal of digital convergence, 2016 Nov, 14(11):305-311*
16. *Hee-Sub Rim, Eun-Bi Jeong, Cheol Oh, Kyeong- PyoKang, “Detection of Unsafe Zigzag Driving Maneuvers using a Gyro Sensor”, The Journal of The Korea Institute of Intelligent Transport Systems, 2011, 10(2):42-54*